From the American Venous Forum

Improvement in the visualization of superficial arm veins being evaluated for access and bypass

Paul S. van Bemmelen, MD, PhD, Patrick Kelly, BS, RVT, and **John Blebea, MD,** *Philadelphia, Penn*

Objectives: **Duplex ultrasound mapping of arm veins is being performed with increasing frequency. Unlike ultrasound testing in other areas, this has never been subjected to a gold standard invasive test to determine accuracy. Duplex mapping appears to have a good predictive value whenever large veins are demonstrated preoperatively, but its ability to accurately measure minimum-sized veins is unproven. In this study, we compared diameter measurements obtained under six different conditions and used the maximum diameter as the comparison gold standard.**

Methods: **A 12-MHz linear probe was used to measure the cephalic and basilic vein cross-sectional diameters at the wrist level in 24 normal volunteers under the following conditions: (1) resting supine with a room temperature of 23° to 24° C, (2) supine with a tourniquet inflated to 65 mm Hg, (3) sitting with the arm dangling, (4) sitting with a tourniquet, (5) sitting after a 2-minute immersion in warm water (44° C), and (6) same with tourniquet. Half the subjects underwent the protocol in a different order.**

Results: **Vein diameters were significantly larger after submersion in warm water compared with supine ($P < .05$, pair-wise multiple comparison procedure, Student-Newman-Keuls method). Assuming the sitting position (from supine) resulted in a decreased arm vein diameter 58% of the time. In 25% of the normal subjects, the cephalic vein size was <2 mm, which increased to >2 mm after warming. All subjects had either a cephalic or a basilic vein at the wrist that was >3.1 mm after warming.**

Conclusion: **Use of warm water immersion before vein diameter measurement in a sitting position, without a tourniquet, will result in significantly larger diameter findings in normal arm veins. These diameters are likely to more closely resemble the venous diameter after distension with arterial pressure. Further studies are needed to see if warming in patients could result in increased utilization of autogenous arm vein for dialysis access and bypass. (J Vasc Surg 2005;42:957-62.)**

Ultrasound mapping of superficial arm veins is becoming a frequently ordered test in the noninvasive vascular laboratory. There is a growing demand for mapping before autogenous fistula construction for chronic hemodialysis in renal failure patients. In addition to classic Cimino-Brescia fistulas, the use of transposition of forearm and upper arm veins and of fistulas at the elbow level is increasing.[1-3] These autogenous fistulas have a better patency than prosthetic grafts and are more resistant to infection.

Historically, the assessment of the cephalic vein at the wrist was made clinically by inspection and palpation with a tourniquet around the arm. Ultrasound size criteria for the cephalic vein are not well defined. In the past, values between 2.0 and 2.5 mm internal diameter have been used for the cephalic vein.

With regard to the basilic vein, no specific examination protocols are found in the ultrasound literature. Although basilic vein size appears to be a separate issue from cephalic vein size, the sizes of the superficial arm veins are not entirely independent of one other in a given subject. This was therefore addressed in the current study as well.

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Correspondence: Paul S. van Bemmelen, MD, Temple University, Surgery, Section of Vascular Surgery, Broad and Ontario Streets, Health Sciences Center, 4th Floor, Philadelphia, PA 19140 (e-mail: vanBemP@tuhs.temple.edu).
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The main purpose of this study was to define the conditions that result in the maximum diameter of the superficial arm veins. This would be likely to predict the potential for the early vein distension after construction of an arteriovenous fistula. Unlike duplex testing in other areas, duplex mapping of arm veins has never been subjected to a gold standard invasive test to determine accuracy. In clinical practice, duplex mapping appears to have a good predictive value whenever large veins are demonstrated preoperatively, but its sensitivity—the ability to detect and accurately measure small veins—is unproven because veins that measure <2 mm are seldom explored.

A number of helpful maneuvers have been mentioned by different authors to optimize conditions, including wrapping the arm in a warm blanket, a sitting patient position, and the use of tourniquets to obtain venous congestion. Performing the ultrasound scan while the arm is submerged in a warm water bath has also been described. Although this approach minimizes probe pressure, it may result in increased electrical hazard from the high-voltage in the probe.

We arrived at six different conditions for vein measurement and compared them. The veins' largest diameter was adopted as a comparison gold standard.

METHODS

Although we were not concerned that the elliptical cross section of superficial arm veins, as opposed to a circular cross section, has major clinical importance, we did have to address this issue for the purpose of developing a reproducible methodology. Gender differences in vein size

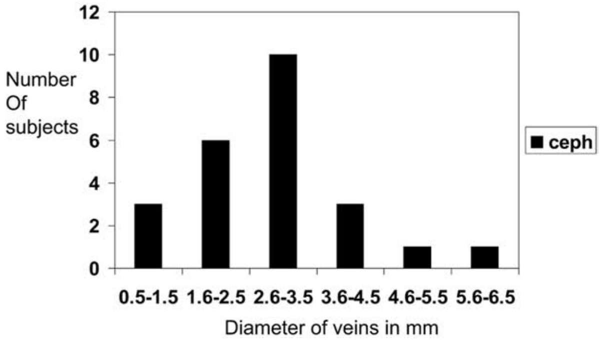

Fig 1. Frequency histogram of the sizes of the cephalic *(ceph)* veins, measured in the sitting position.

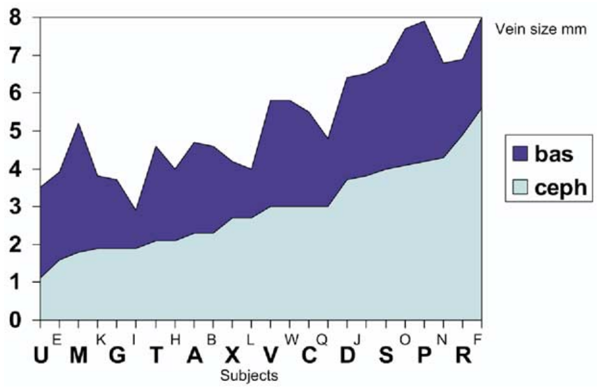

Fig 2. Cephalic *(ceph)* vein size (increasing) **(bottom)** and basilic *(bas)* vein size **(top)** in 24 subjects. The top graph depicts the sum of both diameters.

were assessed as well. The study-protocol was approved by the Institutional Review Board of Temple University.

Ultrasound equipment and technique. General Electric LOGIQ 9 scanners (GE Healthcare, Waukesha, Wisc) were used with a 12-MHz linear array probe. The actual scanning was performed with a 14-MHz frequency. The axial resolution of the ultrasound image is ±3% and the lateral resolution is ±5%. Measurements were performed with electronic calipers on the frozen image in both the anteroposterior (AP) and lateral direction. The calipers were placed at the interface between blood/lumen and vessel wall, and the resulting numbers expressed in tenths of millimeters.

Subjects. Twenty-four healthy subjects volunteered (9 men, 15 women), and their mean age was 32 ± 10 years (range, 22 to 56 years). Seventeen subjects were Caucasian, 5 were African American, and 2 were Asian/Indian. All subjects were of normal body habitus, with a mean weight of 150 pounds [68 kg] (range, 106 to 220 pounds [48 to 100 kg]. All subjects denied diabetes mellitus, renal problems, varicose veins, smoking, or use of vasoactive medications.

The left arm was studied in all subjects. Similar to clinical situations, this would usually be the nondominant side, but no data were collected on this.

Room conditions. All measurements were performed in the same dedicated vascular laboratory room, which was kept at a temperature between 22° and 24° C (71.6° to 75.2° F), confirmed with a digital thermometer. All measurements were performed by the same technologist (P. K.). All AP and lateral measurements were performed once, which in the case of a circular cross-section, yielded two identical measurements. If the AP and lateral measurements were not identical, the average was used.

Tourniquet. Although latex tourniquets are commonly used in daily practice for phlebotomy and vein mapping, we used a narrow pneumatic tourniquet (6 × 83 cm, type SC-5, Hokanson, Bellevue, Wash). This tourniquet can be inflated to a specified pressure (65 mm Hg), which is higher than the venous pressure in the arm but below systolic blood pressure, thereby assuring venous congestion in a reproducible manner.

Warm water bath. The warm water bath consisted of a 54-quart plastic container that was filled with 13 gallons of a mixture of warm and cold tap water until a temperature of between 43° and 44° C by digital thermometer (Traceable, Control Co, Friendswood, Tex) was obtained. Because of the large capacity of this reservoir, the minor decreases that occur in the water temperature during the 2-minute arm submersion can be neglected.

Sequence of measurements. The subjects were divided in two groups: group I (subjects A-L) underwent measurements in the following order:

1. resting supine, with the arm extended by the side of the subject, without the tourniquet;
2. resting supine with the tourniquet inflated to 65 mm Hg for 1 to 2 minutes;
3. sitting with the arm dangling down;
4. sitting with the arm dangling down and an inflated tourniquet;
5. sitting with the arm dangling down, immediately after a 2-minute submersion in warm water (44° C);
6. sitting with the arm dangling down, immediately after a 1-minute resubmersion in warm water (44° C) and the tourniquet inflated to 65 mm Hg for 1 to 2 minutes.

Group II (subjects M-X) underwent the same protocol, except in a different order:

1. sitting without the tourniquet,
2. sitting with the tourniquet,
3. supine without the tourniquet,
4. supine with the tourniquet,
5. 2-minute warm water immersion without the tourniquet, and
6. 1-minute re-immersion with the tourniquet.

AP and lateral measurements were taken of the cephalic and basilic veins at a level 5-cm proximal to the wrist-joint. The order of the measurements (cephalic vs basilic) was varied randomly. The exact location of the measurements was marked on the skin with a marker to allow comparison of the same area under different conditions.

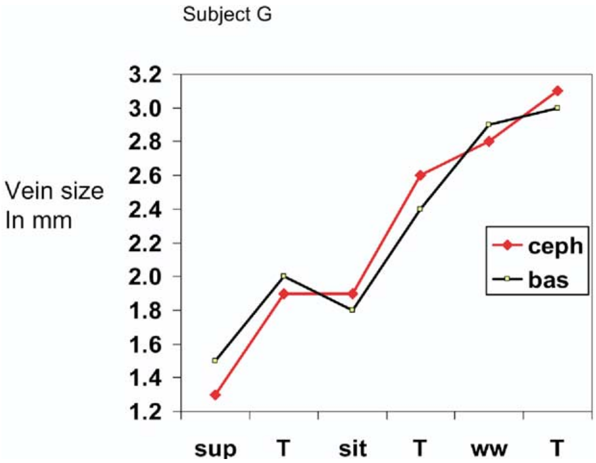

Fig 3. Individual response of a single subject, who started in the supine position: Vein size increased with the application of the tourniquet, while supine. After subsequent removal of the tourniquet, the veins are larger sitting than supine without tourniquet. Warm water gives an additional increase in size. Horizontal axis, moving from left to right: *sup,* supine no tourniquet; *T,* supine with tourniquet; *sit,* sitting no tourniquet; *T,* sitting with tourniquet; *ww,* after warm water immersion while sitting; *T,* after warm water immersion with tourniquet while sitting.

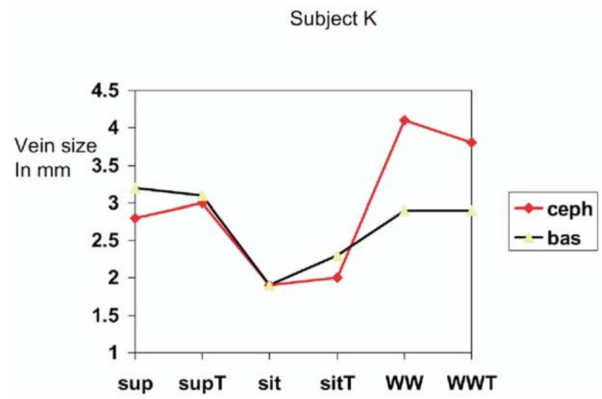

Fig 4. Individual response of a single subject, who started in the supine position: Vein size was not affected much by the application of tourniquet, but a decrease occurred upon assuming the sitting position. Warm water doubled the size of the cephalic vein, but additional application of tourniquet had no effect. Horizontal axis, moving from left to right: *sup,* supine no tourniquet; *supT,* supine with tourniquet; *sit,* sitting no tourniquet; *sitT,* sitting with tourniquet; *WW,* after warm water immersion while sitting; *WWT,* after warm water immersion with tourniquet while sitting.

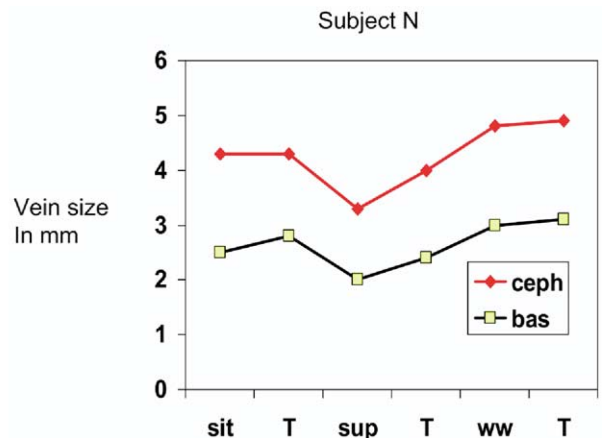

Fig 5. Individual response of a single subject, which started in a sitting position: Little or no effect of tourniquet placement, but decrease in vein-size upon assuming the supine position. Tourniquet increased the supine vein-size, but had little added effect after the warm water-immersion. Horizontal axis, moving from left to right: *sit,* sitting no tourniquet; *T,* sit with tourniquet; *sup,* supine, no tourniquet; *T,* supine with tourniquet; *ww,* after warm water immersion, no tourniquet while sitting; *T,* after warm water tourniquet while sitting.

Statistical analysis. Analysis of variance (ANOVA) and Student's paired t test with Bonferroni correction for multiple comparisons was used. Calculations were done with SigmaStat software (Jandel Scientific, San Rafael, Calif).

RESULTS

The frequency histogram for the sizes of the cephalic vein in the sitting position is shown in Fig 1. This follows a typical bell-shaped distribution, with most diameters in the 2.6-mm to 3.5-mm category. Individual subjects vary in the importance of the cephalic vs the basilic system, and Fig 2 shows this for 24 subjects. In the sitting position, the basilic vein was equal in size or larger than the cephalic vein in seven (29%) of 24 subjects. Figs 1 and 2 show relatively fixed, anatomic features of the venous systems.

The gender differences in vein size were compared after warm water immersion and application of the tourniquet: Although the cephalic vein diameters in males (4.3 ± 1.2 mm) did have a trend to be larger than those in females (3.7 ± 0.7), this did not reach significance. Basilic vein diameters in males and females (3.2 ± 0.5 vs 3.1 ± 0.5) in females did not differ significantly.

The dynamic response of veins to changes in filling and temperature is shown for a representative subject (G) in Fig 3. This subject was first measured in the supine position. Tourniquet application increased the diameter. A further increase in size was noted after warm water immersion. The responses of both the cephalic and basilic vein in this subject were very similar.

A different response was seen in a subject (K) who started in a supine position (Fig 4). Here, a reduction in size occurred upon assuming the sitting position. Again, within the same subject, the responses of cephalic and basilic vein are closely parallel.

Subject N started out in the sitting position and demonstrated a reduction in vein size upon lying down in a supine position (Fig 5).

The mean diameters in millimeters for the cephalic and basilic veins are summarized in Fig 6. In 25% of normal

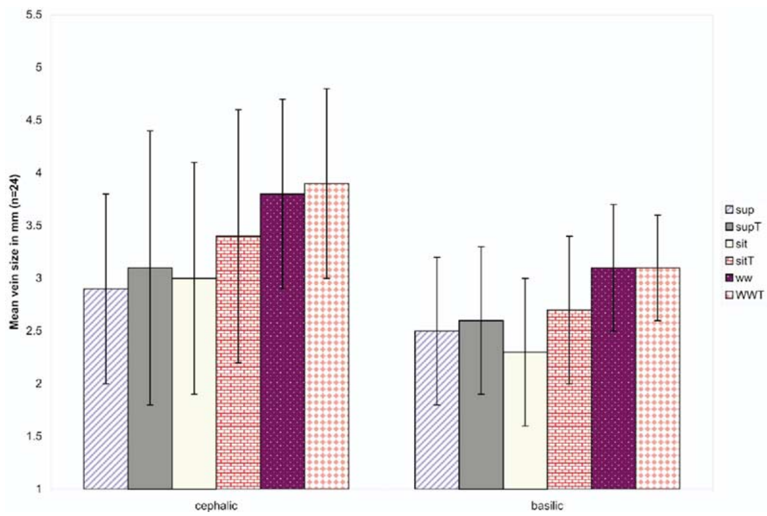

Fig 6. Mean diameters for cephalic and basilic veins under six different conditions: supine *(sup),* supine with tourniquet *(supT),* sitting *(sit),* sitting with tourniquet *(sitT),* after warm water-immersion *(ww),* after repeat warm water immersion with tourniquet *(WWT)*. Whiskers show data ± SEM.

subjects, the cephalic vein size was <2 mm (while supine, without a tourniquet); this increased to >2 mm after warming. All subjects had either a cephalic or a basilic vein at the wrist that was >3.1 mm after warming. The cephalic vein size decreased in 58% of the 12 patients that assumed the sitting position after being supine.

The one-way ANOVA–Student-Newman-Keuls (SNK) for multiple comparisons showed that the differences in the mean values among the measurements of the cephalic veins were greater than would be expected by chance; the difference was statistically significant ($P < .003$). The following pair-wise multiple comparisons (SNK) were significant ($P < 0.05$):

- warm water tourniquet vs supine,
- warm water tourniquet vs sitting, and
- warm water vs supine.

The one-way ANOVA-SNK for multiple comparisons showed that the differences among the measurements of the basilic veins were greater than would be expected by chance; the difference was statistically significant ($P <$ .001). The following pairwise multiple comparisons procedures (SNK) were significant ($P < .05$):

- warm water tourniquet vs sitting,
- warm water tourniquet vs supine,
- warm water tourniquet vs supine tourniquet,
- warm water vs sitting,
- warm water vs supine, and
- warm water vs supine tourniquet.

The differences between measurement values obtained after warm water immersion, without and with a tourniquet, were not significant for either the cephalic or the basilic vein ($P > .05$; Bonferroni *t* test).

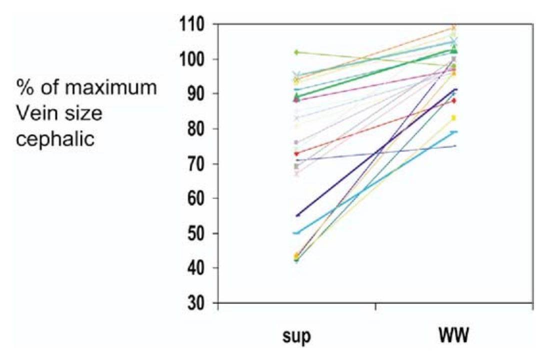

Fig 7. Line graph. *Left column* displays supine cephalic vein diameters expressed as a percentage of maximum diameter *(WWT)*. *Right column* displays the same veins after warm water *(WW)* immersion, with lines connecting the before and after points for each dataset. *Sup,* Supine.

Another way of expressing vein sizes is as a percentage of the same vein's size after warm water immersion with tourniquet application.

In Fig 7, these percentage data are presented in two columns: supine diameter on the left and warm water immersion without a tourniquet on the right. Lines are connecting before and after points for each dataset (24 subjects). This demonstrates that a measurement obtained without warm water immersion may, in some cases, represent only about a third of the veins' fully distended size; in other cases, measurement without warm water may be close to 100% of the fully distended size.

DISCUSSION

The typical duplex examination of the upper extremity has historically been for the evaluation of arm vein thrombosis and is performed in a supine position with the arm

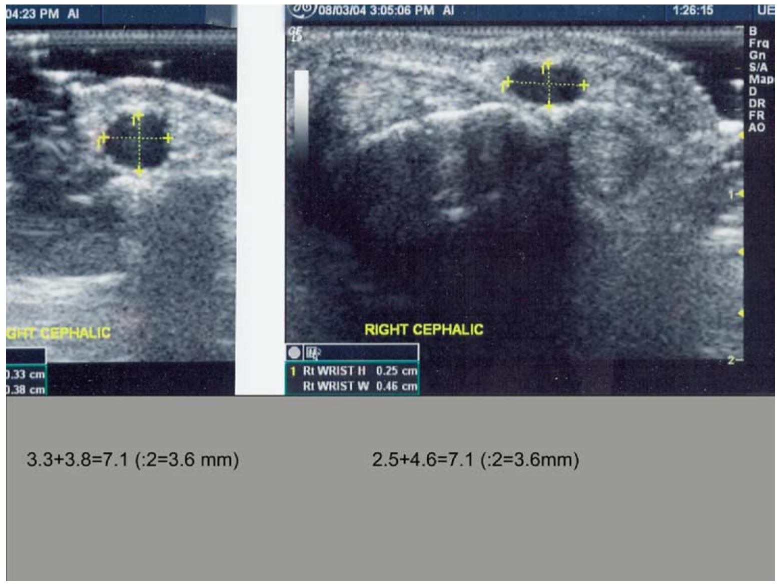

Fig 8. Ultrasound image of the same cephalic vein, without **(left)** and with **(right)** probe pressure. The sum of major and minor ellipse axis remains the same. Note the large amount of gel present between the probe and skin surface on the left hand side of the figure: even with no pressure exerted by the probe, the venous cross section is not perfectly circular.

abducted. The advantages of a supine patient position are stability of the arm, which can be rested on the table or a pillow, and a horizontal probe position, which is comfortable for the examiner, who can stabilize his or her hand on the patient. A disadvantage, however, is that the basilic vein in the forearm cannot be easily imaged with the patient in a supine position because of its posterior location.

Various maneuvers have been described in the literature to enhance the size of superficial arm veins, but their use is variable and infrequent because they are cumbersome and time consuming and their effectiveness has not been systematically documented. Salles-Cunha et al[4] used the combination of tourniquet/sitting position with arm-dependent hand exercise and a heat-pad. For the measurement, they used the largest ellipse. Seeger et al[5] looked at the cephalic vein in the upper arm, but not the forearm. They used a size >2.5 mm as usable for bypass. Tordoir[6] used a supine position with a stand-off device on the probe. No tourniquet was mentioned and the largest diameter was used. Silva et al[2] used tourniquets and a 2-mm size criteria. The University of Washington[7] uses a tourniquet, extra pillows, and a blanket for 10 to 15 minutes. The head is elevated with the arm dependant, a pillow is placed under the forearm, and the arm is slightly flexed. The largest transverse diameter is measured and a size of >2 mm is considered adequate for bypass.

Lastly, complete submerging of the forearm, with the use of water as the ultrasound medium, has been described by Libertiny et al.[8] Scanning was performed while the forearm was placed in the warm water container, and no tourniquet was used.

One would expect a circular diameter with complete filling,[9] but we usually found differences around 15% between AP and lateral diameter measurements. Although absolute vein diameter may not be as important as vein-patency/continuity and the absence of vein wall fibrosis, the best way to ascertain that forearm veins will fully distend under arterial pressure is to maximize distension during the preoperative mapping. Increasing the sensitivity of vein measurements may result in a higher utilization of autogenous fistulas, provided that these veins are indeed of good quality.

Several factors may affect the distensibility of arm veins. Zsoter et al[10] found increased distensibility of arm veins in patients with varicose veins; therefore, subjects with clinically evident varicose veins were excluded from our study. Likewise, thermally induced cutaneous vasodilation and vascular reactivity may be affected by aging[11] or race.[12] Furthermore, the elasticity of veins differs between the very young and very old,[13] so age distribution and racial diversity are relevant with regard to the subjects in this study.

Many factors will affect the measured vein sizes, and they fall into static and dynamic categories. Static factors include such things as the anatomic size related to subject gender and muscle-mass, which tends to be normally distributed,[14] and the anatomically relative dominance of the cephalic vs basilic system within the subject.

On the other hand, among dynamic factors are the intraluminal filling pressure (eg, position of the arm in relation to the heart) in addition to central venous pressure and the venous wall tone, which is related to room temperature, neural stimulation, and local release of nitric oxide in response to local shear stress. Lastly, external pressure from the ultrasound probe could affect the measurement.

Ideally, a method will give a consistent estimate of the "actual" size. Given the above variability, we need to consider which vein size is relevant. The vein is a collapsible tube, so its size ranges from zero to a "maximum" size that, because of the elastic properties of collagen, is close to the vein size at bursting pressure. The venous volume-pressure relationship curve becomes nearly horizontal shortly after the elliptical cross section has become circular.[9]

When a superficial arm vein is completely embedded in subcutaneous tissue and the intraluminal pressure is much higher than the external probe pressure, it is possible to obtain a circular cross section. In most situations, however, we found a smaller AP than transverse measurement.

When an elliptical tube is distended by an increase in transmural pressure, the major axis decreases and the minor axis increases.[15] Small variations in either filling pressure or probe pressure will therefore affect both of these measurements, but not the mean of the minor and major axis (Fig 8). A possible explanation for the apparent reduction in diameter of arm veins upon assuming the sitting position from a supine position may be a reflex contraction of superficial veins to avoid peripheral pooling and hypovolemia when assuming a vertical position.

CONCLUSION

Warm water immersion yields larger measurements than without. These are more likely to resemble the venous diameter after distension with arterial pressure. If adequate veins are demonstrable without warm water immersion, the study may be considered a complete study. However, if veins appear small, warm water immersion should be performed followed by measurement in a sitting position, without a tourniquet.

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